REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE

2. REPORT TYPE
Paper

3. DATES COVERED

4. TITLE AND SUBTITLE

Airborne Separation Video System

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Rob Crandall

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Air Warfare Center Aircraft Division
22347 Cedar Point Road, Unit #6
Patuxent River, Maryland 20670-1161

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Due to decreasing DOD funds, the development of new tools to increase the efficiency of air vehicle/store compatibility testing was required. This need led to the design, manufacture, and test of the ASVS. The ASVS is a high-speed digital imaging system that addresses the inefficiencies inherent in high-speed film cameras as the primary recording medium for store separation events.

In May 2000, the ASVS was used in a production capability for the first time. The maiden flight occurred on an F/A-18E/F dropping a Joint Direct Attack Munition (JDAM). Additional F/A-18 testing using the ASVS has included separation testing of the AIM-9X and ASRAAM missiles and Joint Stand Off Weapon (JSOW) smart weapon.

15. SUBJECT TERMS

Airborne separation video system (ASVS); Joint Direct Attack Munition (JDAM): Joint Stand Off Weapon (JSOW)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Rob Crandall
a. REPORT	b. ABSTRACT	c. THIS PAGE		18	19b. TELEPHONE NUMBER (include area code) (301) 342-4348

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

20010406 118

AIRBORNE SEPARATION VIDEO SYSTEM

Rob Crandall
Telephone: 301-342-4348 Email: crandallrd@navair.navy.mil

Air Vehicle/Store Compatibility Division (4.11.2)
Naval Air Warfare Center – Aircraft Division
21960 Nickels Road, Unit 4
Patuxent River, MD 20670-1539

ABSTRACT

1. Due to decreasing DOD funds, the development of new tools to increase the efficiency of air vehicle/store compatibility testing was required. This need led to the design, manufacture, and test of the Airborne Separation Video System (ASVS). The ASVS is a high-speed digital imaging system that addresses the inefficiencies inherent in high-speed film cameras as the primary recording medium for store separation events. Anticipated benefits from the ASVS are multiple buildup separation test points per flight (the store separation images can be telemetered to a ground station for qualitative analysis for near real-time analysis), a pre-release preview capability to ensure the cameras are functioning and image exposure is adequate, quicker turnaround between flights (no film processing requirements); and lower costs associated with not having to purchase, process, and dispose of the film. Following an extensive contractor test period, during which Specification requirements were evaluated, the Navy conducted suitability tests. Phase I of the government suitability tests consisted of ground tests in which a Mk 82 bomb was dropped from an F-18 into a pit. Phase II of the government suitability tests consisted of flight tests during which F-18 authorized stores were released. The NTTC-P camera maximum illumination and dynamic range deficiencies are such that the ASVS can conduct it's primary mission (recording of store separation events) but may require operator compensation (awareness of aircraft heading relative to the sun and/or more frequent shutter changes). The anti-blooming deficiency in the NTTC-P camera has been corrected in the NTTC-V camera. The ASVS digital images provide sufficient resolution to make qualitative analysis consistent with film. The digital format and higher contrast of the ASVS images will allow for a quicker turnaround of a six degree-of-freedom (6-DOF) solution to the engineer. The aircrew interface to the ASVS will allow real-time changes (image exposure) to increase the image quality. The Data Transmission System (DTS) image quality was sufficient for the near real-time analysis of a store separation event and will allow for multiple releases in a buildup test program. The DTS image exposure information was sufficient for the determination of optimal image exposure and will allow for improved data quality due to the improved image quality. The use of the aircraft store release pulse to trigger the ASVS cameras will ensure the cameras are turned ON/OFF at the appropriate time. When the images are properly exposed, the ASVS is a suitable replacement for film and can be used to increase the efficiency of the air vehicle/store compatibility test process.

2. In May 2000 the ASV system was used in a production capability for the first time. The maiden flight occurred on an F/A-18E/F dropping a Joint Direct Attack Munition (JDAM). Additional F/A-18 testing utilizing the ASV system has included separation testing of the AIM-9X and ASRAAM missiles and Joint Stand Off Weapon (JSOW) smart weapon.

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED.

CLEARED FOR
OPEN PUBLICATION
14 Feb 01
PUBLIC AFFAIRS OFFICE
NAVAL AIR SYSTEMS COMMAND
H. Howard

AIRBORNE SEPARATION VIDEO SYSTEM OVERVIEW

3. The ASV program was initially designed with only a Near-Term Test Capability (NTTC) and a Long-Term Test Capability (LTTC). The NTTC was, relative to the LTTC, a low resolution, large camera and would be delivered as soon as possible so that the government could start taking advantage of a digital imaging capability. The LTTC camera would be delivered at a later date allowing industry to advance to the point where the technical hurdles associated with designing and manufacturing a smaller, higher resolution camera could be overcome. Since program kick-off, additional camera requirements have been identified. They are the NTTC-P (original NTTC), NTTC-V (LTTC size with NTTC-P resolution), NTTC-RS (remote sensor with NTTC-P resolution) and the color versions of the above monochrome cameras. Characteristics unique to each camera are discussed below.

Airborne Separation Video System

4. The ASVS is a ruggedized, high-picture rate, digital imaging system manufactured by DRS Photronics Systems of Oakland, New Jersey. It consists of a Controller/Recorder Unit or Multi-system Controller, Cockpit Control Unit, Ground Interface Unit, up to any combination of 16 NTTC and LTTC digital cameras, and the associated cabling and connectors. All ASVS components, with the exception of the GIU, have been ruggedized for the flight environment. Each unit uses 115 VAC (400 Hz) or 28 VDC power.

Cockpit Control Unit (CCU)

5. The CCU is the operator interface for controlling the ASVS while airborne. It contains an ON/OFF switch, a RESET button, an ENTER button, six light-emitting diodes to indicate system status, and a liquid crystal display to communicate with the operator. The unit is 5.8 in. x 4.0 in. x 5.7 in. and weighs 4.3 lb. The CCU is shown in figure 1.

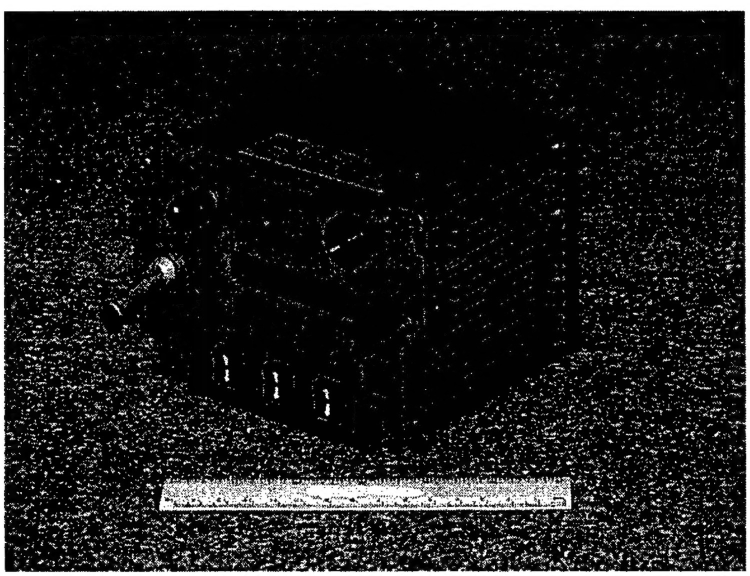

Figure 1. Cockpit Control Unit (with 6 inch ruler)

Controller/Recorder Unit (CRU)

6. In addition to being the ASVS interface to the DTS, the CRU saves the store separation images recorded by the cameras in nonvolatile memory so that aircraft power transients do not result in permanent loss of images. The CRU's high-density hard drive has a storage capacity of 9.0 Gbytes and can save 64,000 NTTC images or 16,000 LTTC images (represents 1000 high resolution images from each of 16 cameras) using approximately 1.6:1 lossless JPEG compression. The unit is 6.3 in. x 7.4 in. x 4.8 in. and weighs 8.4 lb. The CRU is shown in figure 2.

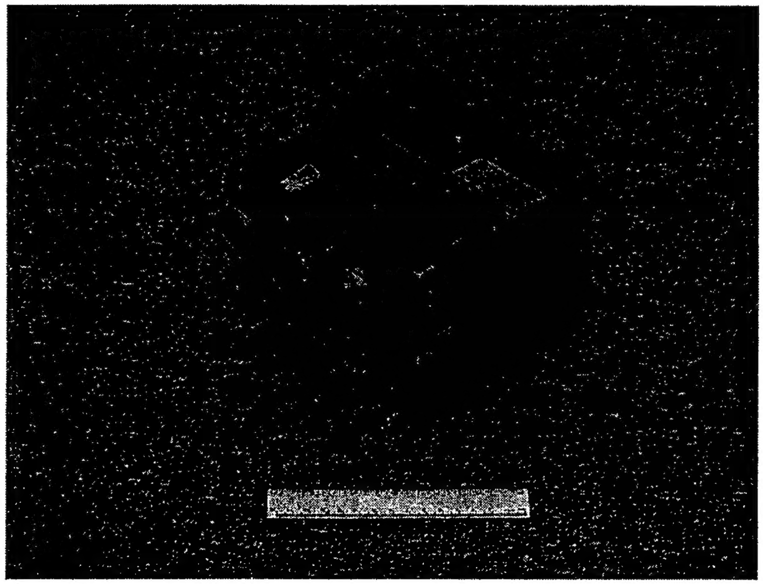

Figure 2. Controller/Recorder Unit (with 6 inch ruler)

Multi-system Controller (MSC)

7. The MSC is an enhanced version of the CRU. In addition to maintaining the functionality of the CRU it provides faster image read/write capability, a remote, wireless control capability, is sized such that it will fit into a 7.0 inch diameter pod, contains an easily removable hard drive, and allows for declassification if it ever contains classified images. The unit is 3.7 in. x 2.7 in. x 3.9 in. and weighs 1.7 lb. The MSC is shown in figure 3.

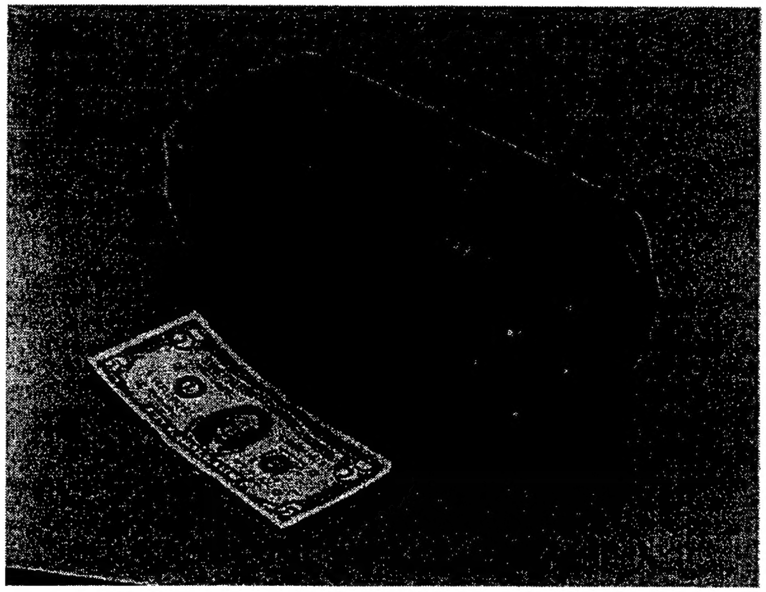

Figure 3. Multi-System Controller (shell only)

NTTC-P Digital Camera

8. The NTTC-P digital camera (up to 16 per system), operating at 30, 200, or 400 pictures per second (pps), can save 1,000 monochrome images per event. When the camera's memory is full, the images are downloaded to the CRU/MSC where they are stored in nonvolatile memory. The two primary functional capabilities of the camera are that it can be triggered to record images via the store release pulse and it can record images before the receipt of the store release pulse (the previous 1,000 images are stored in the camera at any one time). This allows the cameras to start recording without specific aircrew action and, that because of electrical and mechanical delays in the aircraft armament system, store first motion is not missed. After the images are downloaded to the CRU/MSC, the cameras can be RESET to record additional images. ASVS Specification requires the NTTC-P camera to be able to measure high-contrast edges separated by a maximum of two inches at a range of 28 feet in a field of view of 39 feet (horizontal) and 39 feet (vertical). The NTTC-P camera is 8.7 in. x 5.4 in. x 4.3 in. and weighs 9.9 lb. The NTTC-P is a prototype camera only. The NTTC-P CCD contains a monochrome, 512 x 512 pixel array and each pixel has 8 bit resolution.

NTTC-V Digital Camera

9. The NTTC-V digital camera is the first of several camera versions planned for production and is similar to the NTTC-P camera with the following exceptions. The NTTC-V camera is smaller and lighter, i.e., 2.6 in. x 3.4 in. x 7.4 in. and weighs 5.0 lbs. The smaller size of the NTTC-V represents a 70% reduction in the size of the NTTC-P. The NTTC-V camera uses the next generation CCD that markedly improves image quality. The NTTC-V will be produced in monochrome and color versions. The NTTC-V digital camera is shown in figure 4.

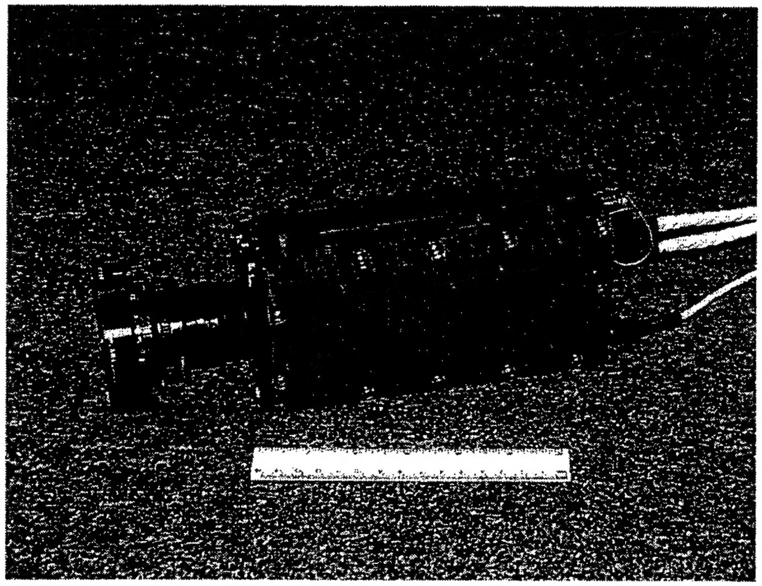

Figure 4. NTTC-V Digital Camera (with 6 inch ruler)

NTTC-RS (Remote Sensor) Digital Camera

10. The NTTC-RS digital camera is functionally similar to the NTTC-V camera however is quite different physically. The NTTC-RS CCD package can be separated from the camera memory and electronics by up to 30 ft. This will allow a minimum drag configuration because only the small CCD package will be exposed to the airflow. The NTTC-RS camera is 3.7 in. x 2.7 in. x 3.9 in. and weighs 1.7 lb. The NTTC-RS digital camera is shown in figure 5.

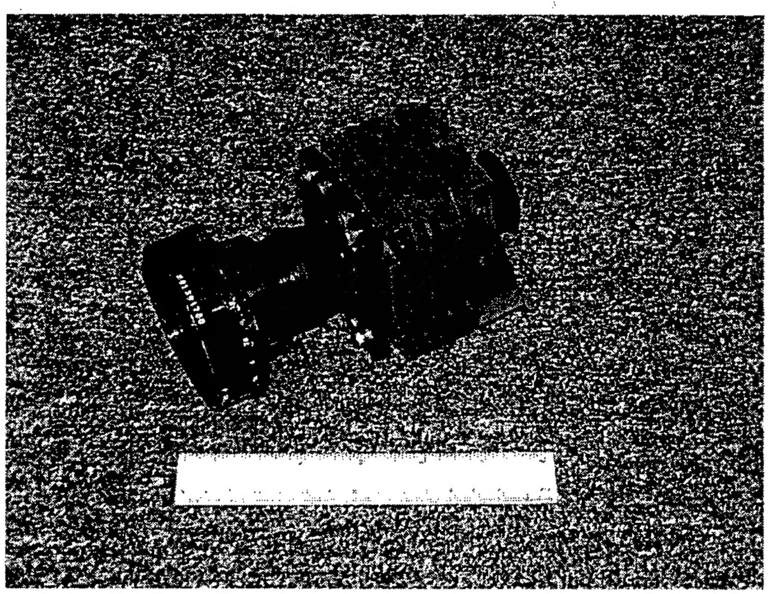

Figure 5. NTTC-RS Digital Camera (with 6 inch ruler)

Long-Term Test Capability (LTTC) Digital Camera

11. The LTTC digital camera will be similar to the NTTC-V camera with the following exception. The LTTC camera will have a 1024 x 1024 complementary metal-oxide semiconductor (CMOS) imager. This larger pixel array requires image file sizes that are 4 times larger than the NTTC camera. The ASVS Specification requires the LTTC camera to be able to measure edges separated by a maximum of one inch at a range of 28 feet in a field of view of 39 feet (horizontal) and 39 feet (vertical). The LTTC camera is currently in design with production expected to begin in March 2001.

Ground Interface Unit (GIU)

12. The GIU is the primary means of interfacing with the ASVS on the ground and is used to configure the ASVS for flight. This includes setting the camera's picture rate, shutter speed, record time, trigger delays, which cameras will record images for each release, and how the cameras are triggered. The GIU is also used to download the images from the CRU/MSC during postflight operations for subsequent viewing and analysis.

Data Transmission System (DTS)

13. The DTS (airborne and ground equipment) is used to transmit pre-release images to the ground for preview prior to store release. Additionally, store separation images can be sent to the ground through the DTS for near real-time qualitative store separation analysis. The DTS consists of an interface insertion generator (ASVS interface box), video encoder, encryptor (or randomizer), and transmitter. Whereas the insertion generator was developed specifically to interface with the ASVS, all other components, including the ground receiving/decoding/display equipment, are already in use at government test facilities. The ASVS Specification requires 1000 images from each of 7 cameras to be transmitted to the ground in less than 15 minutes.

Qualitative Data Reduction System (QDRS)

14. The QDRS is a Gateway personal computer. It contains a 500 MHz Pentium III processor, 18.0 Gbyte removable hard drive, 256 Mbytes of RAM, a DRS-proprietary Color Video Processor (CVP) card, a read/write CD drive, an Exabyte Mammoth tape drive, and a 100 GB RAID (redundant array of independent disks). The CVP card is used to decompress and reconstruct color ASV images. The Exabyte Mammoth tape drive is used to read ASV images into the QDRS. The QDRS is used to view the ASVS digital images to make a qualitative assessment of the store's separation characteristics. Special QDRS software will be developed to meet the functional capabilities determined by the government.

ASVS Benefits

15. Prior to release, images can be transmitted to the ground where personnel can evaluate image quality for possible exposure changes. This gives the engineer the best images possible for analysis. After the test, the images can be transmitted to the ground for a near-realtime analysis that provides the capability to conduct multiple build-up points per flight. Multiple buildup points per flight represents the largest benefit from digital video as it could greatly reduce test schedules (fewer flights) and test cost (lower flight hour and range costs). Hands-off camera activation will free the aircrew from having to turn the cameras ON/OFF during a high-workload activity, i.e., when trying to fly a high risk, close tolerance test point. Because the ASV images are already in a digital

format the significant cost/time associated with processing film for qualitative analysis and digitizing the film for quantitative analysis is avoided. Film purchase costs are avoided as well. Additionally the editing, playback, and archiving are greatly facilitated by the digital video format.

ASVS Functional Capabilities

16. The following is a list of the most important functional capabilities of the ASV system.

- Camera picture rates of 30, 200, and 400 pps
- Camera memory of 1000 images
- Control and download data from any combination of 16 NTTC and LTTC cameras
- Maintain digital image format from acquisition to display
- Compatible with government owned transmission equipment
- Compatible with existing camera mounts and lenses
- Transmit images (7 cameras) from the aircraft to the ground within 15 minutes
- Download images (16 cameras) from the aircraft to the GIU within 60 minutes

ASVS Operational Capabilities

17. The following is a list of the most important operational capabilities of the ASV system.

- CRU storage capacity of 1000 images from up to 16 LTTC cameras
- Accept external signal, i.e., store release pulse from aircraft to trigger cameras
- Negative trigger delay, i.e., allows images to be recorded prior to first store motion
- Preview
- Auto-exposure
- Sync all cameras' shutter opening times to each other
- Placing of cameras into specific groups, i.e., Left or Right
- Synchronized to IRIG time

ASVS Environmental Capabilities

18. One of the greatest program challenges was ruggedizing the cameras, and to a lesser degree the CCU and CRU, for the flight environment. The following is a list of the most important environmental capabilities of the ASV system.

• Temperature/Altitude	-55°C to +71°C, 0 to 50K ft, ASVS On/Off
• Vibration	Buffet, 15.1 Grms, Nonbuffet, 27.2 Grms, ASVS On/Off
• Shock	20 Gs, 7.5 msec, 3 shocks/direction, ASVS On 40 Gs, 7.5 msec, 3 shocks/direction, ASVS Off
• Humidity	10-24 hr cycles, 95% humidity, 30-60°F
• Power	MIL-STD-704
• Acceleration	42 Gs each direction, sustained 1 minute
• EMI	MIL-STD-461/462
• Salt/Fog	48 hrs, 95°F, 5 parts salt/100, 7.0 pH

Operational Scenario

19. Prior to take-off, the ASV Mission is loaded into the CCU and the ASV system is preflighted. An ASV Mission consists of specific events (DTS PREVIEW, manual or trigger CAPTURE, CRU or DTS DOWNLOAD, and ERASE) which are executed in a specific order for specific camera settings (picture rate, camera record time, shutter duration, trigger delay). System preflight includes a Built-in-Test of each individual component and an overall system check. On application of power, the ASVS initializes and conducts Built-in-Test. After a 5 minute initialization period, the system is ready for sequencing through the Mission events when commanded by the operator. Prior to release, the image exposure can be verified using the PREVIEW function via the DTS. After the release, the data will either be stored permanently in digital file format onboard the CRU/MSC and/or telemetered to the ground. During a test event, the operator or a store release pulse triggers the designated group of cameras to begin recording. Following successful data transfer, the pilot is able to reset the system for additional events. Upon landing the data is downloaded from the aircraft and transfered into the QDRS for analysis.

NAWCAD PAX GROUND/FLIGHT TESTS

Purpose

20. The purpose of the test was to assess the suitability of the ASVS's qualitative and quantitative analysis capability for aircraft/store certification tests. In addition to comparing the ASVS images to film, the specific steps necessary to incorporate digital imagery into the store certification process were evaluated.

Tests and Test Conditions

21. This test program consisted of 1 ground test, 1 captive carriage flight, and 11 separation flights totaling 10.1 hr. The purpose of the ground test was to evaluate, under controlled conditions, the suitability of ASVS's qualitative and quantitative analysis capability prior to commencing with flight tests. The purpose of the captive carriage flight was to ensure the ASVS could withstand the tactical jet flight environment. The purpose of the separation flights was to provide store separation events so that a comparison could be made of the qualitative and quantitative analysis capabilities of film and ASVS images.

Test Criteria

22. Film, and the processes associated with it, was the test criteria as it is the medium and process currently in use. At the heart of the evaluation was whether or not the ASVS images contained sufficient resolution (i.e., can small, low contrast items, such as arming lanyards be seen?) to allow the store separation engineer to analyze all events associated with a store separation event. This include store-to-store and store-to-aircraft contact, fin opening time, lanyard motion, nose fuse arming sequence, and store trajectory. The quantitative analysis capability provided by ASVS digital images was also evaluated.

Qualitative Data Reduction and Analysis

23. Store certification engineers conducted a qualitative analysis of the store trajectory, lanyard motion, fin opening times, and nose fuse arming of each flight to determine if the ASVS images contain sufficient resolution to effect adequate analysis. The functional capability of the QDRS was

evaluated for image download rate, decompression/conversion rates, archival capacity, ease of use, ergonomic design, etc. IRIG time stamps and flashbulbs were used to correlate film and ASVS images.

Quantitative Data Reduction and Analysis - Ground

24. The ASVS digital images were evaluated for their ability to provide an accurate photogrammetric (precise measurements using film or digital images), six degree-of-freedom (6-DOF) solution for x, y, and z position and pitch, roll, and yaw attitude through a series of ground tests. Ground tests were conducted by recording bomb drops from an F/A-18 aircraft, calculating a 6-DOF solution using film and ASVS, and then comparing the two sets of test data to control data. Because of the dynamic nature of a store separation event, a means was required to determine the actual position/attitude of the bomb while minimizing bomb position/attitude error. This was done by optimally locating "control" film cameras with regard to camera distance, lens, and field-of-view (FOV) so that the control data error would be minimized. Upon completion of the control camera 6-DOF error assessment (average position error was 0.12 inches and the average attitude error was 0.26 degree), a comparison of the ASVS and film 6-DOF solutions was made by comparing each solution from actual test drops to the control data and noting the differences. To simulate aircraft configurations, the test camera distances were varied for each release while maintaining 5.9 mm lenses. All images (ASVS, film, and control) were combined with the appropriate lens calibrations and camera orientations, and using triangulation, calculated the 6-DOF motion of the store. The analysis resulted in three 6-DOF solutions; ASVS, film, and control. A comparison of the ASVS solution versus the control solution, and of the film solution versus control solution provided the basis for determining ASVS's suitability for quantitative analysis.

Quantitative Data Reduction and Analysis - Flight

25. The flight quantitative analysis was conducted by calculating a three-camera, 6-DOF solution for MK 80 series bomb tests using ASVS and film images and then comparing those solutions to each other. The same basic process was used for flight quantitative analysis that was used for the ground quantitative analysis. However, the flight test did not allow for the recording of control data as discussed previously, and therefore, a direct film to ASVS comparison was made. Whereas during the ground test, ASVS and film 6-DOF solutions were compared indirectly through the control data, the flight ASVS and film 6-DOF solutions were compared directly. The standard of comparison was whether or not the ASVS time history matched the film time history. The film 6-DOF solution was not considered to be more accurate than the ASVS 6-DOF solution but was used as the standard because it is the current, accepted medium for 6-DOF solutions.

TEST RESULTS AND DISCUSSION

Maximum Illumination Capability

26. The maximum illumination capability of the NTTC-P digital camera was evaluated for its effect on the ability to conduct a qualitative analysis of a store separation event. The maximum illumination capability is the amount of illumination the camera can receive without pixel saturation. Saturation occurs when the internal camera analog-to-digital converter is saturated (>255 in digital value) and renders the camera unable to differentiate between varying levels of illumination above the saturation level. Without a sufficient maximum illumination capability, the camera becomes saturated at relatively low illumination levels and image quality is degraded. The maximum

illumination level of the NTTC-P was determined to be approximately 10,000 lux in laboratory tests. Illumination levels above 40,000 lux are not unusual during flight tests. The effect of low maximum illumination levels is that the store separation event data (store outline, arming lanyards, 6-DOF targets, bomb rack gas porting, flares, chaff, etc.) may not be discernible. The low maximum illumination level will reduce the ASVS qualitative analysis capability by providing less than optimum images for analysis. It has been noted during subsequent laboratory tests that the NTTC-V camera has improved the maximum illumination capability to about 18,000 lux. An image showing the effect of non-compliant maximum illumination is shown in figure 6.

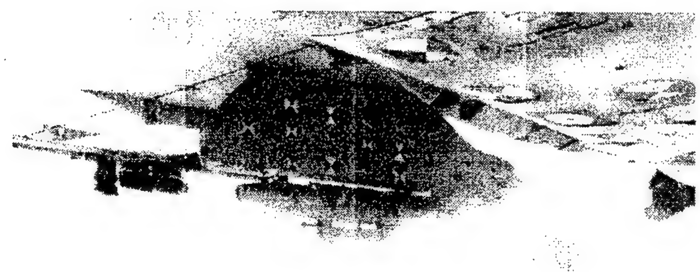

Figure 6. Non-compliant Maximum Illumination

Antiblooming

27. The antiblooming capability of the NTTC-P digital camera was evaluated for its effect on the ability to conduct a qualitative analysis of a store separation event. Antiblooming is the capability of a CCD to prevent the charge from a saturated pixel to spill over into an adjacent pixel. Without sufficient antiblooming, relatively low levels of illumination in a specific area of the CCD would bleed into adjacent pixels causing those pixels to become saturated and reduce the ability to conduct qualitative or qunatitative analysis. During previous laboratory testing, it was determined the antiblooming capability of the NTTC-P digital camera was noncompliant (approximately 300:1 vice 1000:1). The effect of noncompliant antiblooming is that the store separation event data (store outline, arming lanyards, 6-DOF targets, bomb rack gas porting, flares, chaff, etc.) may not be discernible. Noncompliant antiblooming capability will reduce the NTTC-P digital camera's qualitative analysis capability by providing less than optimum images for analysis. The noncompliant antiblooming capability should be corrected as soon as practicable. An image showing the effect of non-compliant antiblooming is shown in figure 7. The antiblooming capability of the NTTC-V digital camera is fully compliant.

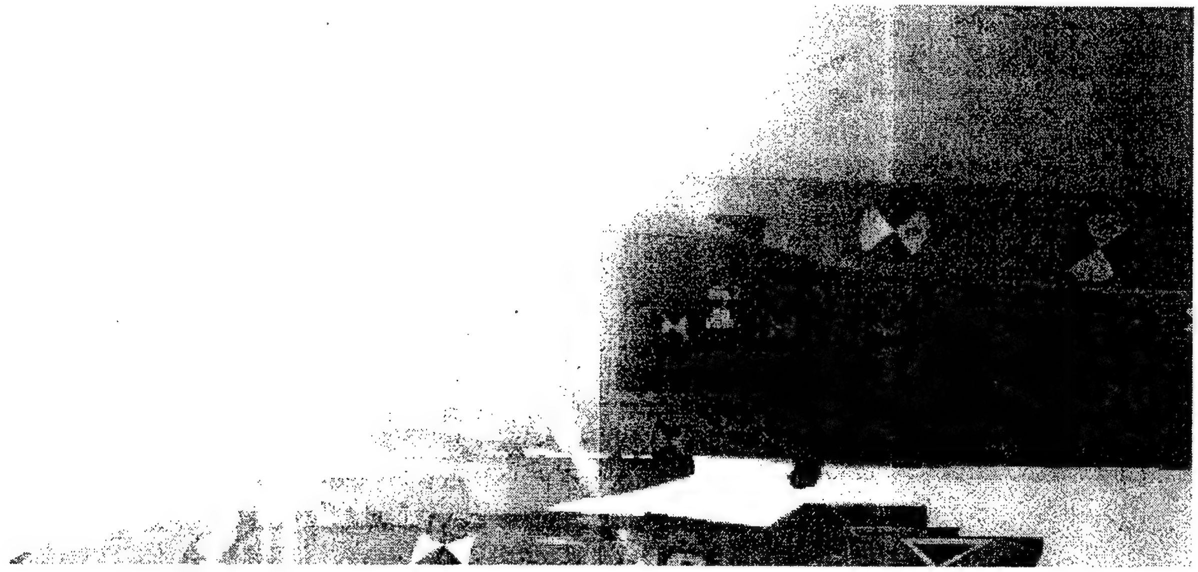

Figure 7. Non-Compliant Anti-Blooming

Dynamic Range

28. The dynamic range of the NTTC-P digital camera was evaluated for its effect on the ability to conduct a qualitative analysis of a store separation event. The dynamic range is the range of illumination a single image can detect. Without sufficient dynamic range, as the light level changes for a given exposure, image contrast will degrade faster. Insufficient dynamic range also manifests itself when a single image contains a dark area and a bright area. If sufficient dynamic range is not available, a particular area of the image will be too light or too dark. During previous laboratory testing, it was determined the dynamic range of the NTTC-P digital camera was noncompliant (approximately 44 dB vice 50 dB). The effect of noncompliant dynamic range is that the store separation event data (store outline, arming lanyards, 6-DOF targets, bomb rack gas porting, flares, chaff, etc.) may not be discernible. Noncompliant dynamic range will reduce the NTTC-P digital camera's qualitative analysis capability by providing less than optimum images for analysis. An image showing the effect of non-compliant dynamic range is shown in figure 8. The noncompliant dynamic range should be corrected as soon practicable.

Figure 8. Non-Compliant Dynamic Range

Qualitative Analysis Capability

29. The ASVS digital images were evaluated for the capability to conduct a qualitative analysis of a store separation event. This analysis includes the capability to view store outline, arming lanyards, nose fuse arming vanes, fin opening, bowtie targets, ejector gas porting, and ejector feet movement. The ASVS images were clear and store separation objects (store outline, arming lanyards, nose fuse arming vanes, fin opening, bowtie targets, and ejector feet) were easily discernible. The ASVS digital images provide sufficient resolution to make qualitative analysis consistent with film. When properly exposed (i.e., no problems associated with maximum illumination, dynamic range, or antiblooming), the ASVS digital images are satisfactory for qualitative analysis of store separation events. Figure 9 shows some of the detail present even in a relatively low resolution image (compared to full resolution computer monitor image) from the flight tests.

Figure 9. Sample ASVS Store Separation Image

Quantitative Analysis Capability

30. The ASVS digital images were evaluated for their ability to provide an accurate 6-DOF solution during ground and flight tests. The time required to digitize the film images is not incurred when using ASVS image files (already in digital format). Additionally, the ASVS image file size is 1/4 the digitized film image size and requires less time to display. Furthermore, the contrast of the ASVS images are better then the digitized film images making tracking of the bowtie targets easier. The digital format, smaller file size, and higher contrast of the ASVS images will allow for a quicker turnaround of a 6-DOF solution to the engineer. The ASVS 6-DOF solution was comparable with the film 6-DOF solution and will allow the store/certification community to take advantage of the many benefits associated with digital imagery. Figure 10 shows the excellent correlation between the ASV and the control 6-DOF solutions for a MK 82 released from an F-18 wing station into a pit. Figure 11 shows the excellent correlation between the ASV and film 6-DOF solutions for a MK 82 released from an F-18 wing station.

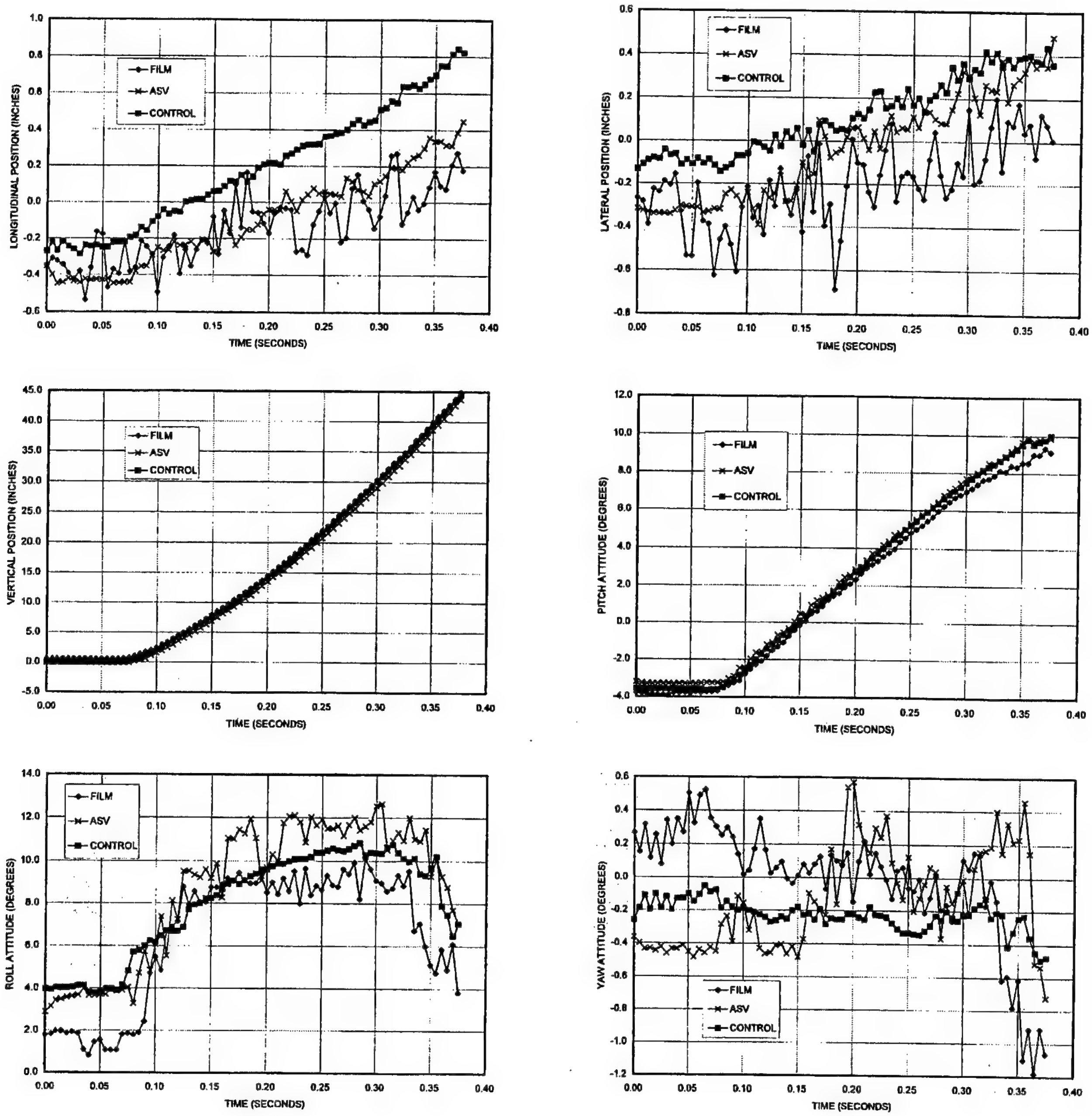

Figure 10. Sample ASV, Film and Control 6-DOF Comparison (Ground Test)

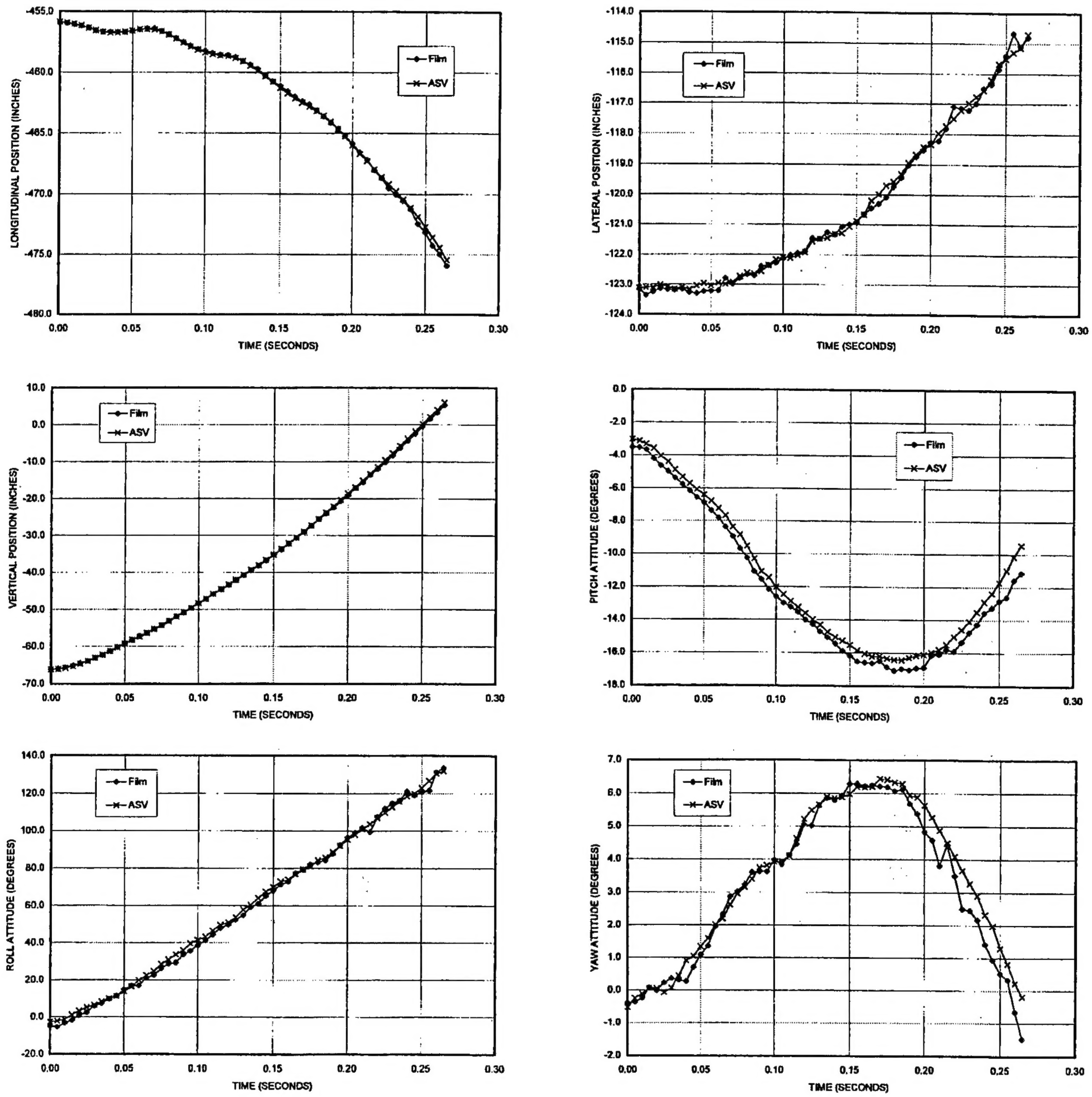

Figure 11. Sample ASV and Film 6-DOF Comparison (Flight Test)

Ground Interface Unit Evaluation

31. The GIU was evaluated for its interface capabilities with the ASVS for Mission setup, preflight checkout, and postflight data download. Mission setup, preflight checkout, and postflight data download were conducted in accordance with the procedures recommended by the contractor and modified by NAWCAD Patuxent River personnel. Mission setup and preflight checkout was easily and quickly accomplished. The ASVS allows for great flexibility in changing camera configurations at the last minute. Postflight actions were easily accomplished. The GIU is satisfactory as the interfacing with the ASVS on the ground.

Aircrew Interface

32. The aircrew interface to the ASVS (through the CCU) was evaluated during each flight. Powering up the system was easily accomplished by selecting the power switch following the aircraft engine startup sequence. The ASVS BIT and startup sequence was logical and was quickly accomplished (approximately 4 min 45 sec). The CCU switches were positive feel, easily selected, and easily understood. The displays and indicator lights were easily readable, even in direct sunlight. The aircrew interface (CCU) to the ASVS is satisfactory for the aircraft/store certification mission. The aircrew interface to the ASVS will allow real-time Mission changes (image exposure) to increase the image quality.

Data Transmission System

33. **Image Quality** The DTS image quality (512 x 512 ASV digital image converted to RS-170 analog image) was evaluated during each flight. DTS images were used to conduct near real-time analysis of a store separation event. When properly exposed, DTS DOWNLOAD image quality was sufficient for store separation analysis (store outline, arming lanyards, nose fuse arming vanes, fin opening, bowtie targets, and ejector feet). The DTS image quality was sufficient for the near real-time analysis of a store separation event and will allow for multiple releases per flight in a buildup test program.

34. **Preview for Real-Time Exposure Changes** DTS PREVIEW was evaluated for making real-time exposure changes. DTS images were used to evaluate image exposure prior to a release. DTS PREVIEW image exposure information was indicative of actual image exposure and effected real-time changes of image exposure to improve image exposure when necessary. The DTS image exposure information was sufficient for the determination of optimal image exposure and will allow for improved data quality due to improved image quality.

Image Transfer Time (Airborne)

35. The time required to transfer image files from the NTTC camera to the CRU and DTS while airborne was evaluated to ensure a near real-time analysis could be accomplished. The time required to transfer 1000 images from each of three NTTC cameras to the CRU and DTS was 2 min 25 sec. If seven NTTC cameras are considered, the transfer time would be 5 min 38 sec. The airborne data transfer time for NTTC cameras is satisfactory and will allow for the download of store separation images to the ground for analysis, thus allowing multiple releases per flight. If the transfer rate is not increased, the transfer time of LTTC image files (four times larger than the NTTC image files) will be too long for near real-time analysis. It is anticipated the airborne image transfer time associated with the MSC will decrease allowing for near real-time analysis with the LTTC cameras.

Image Transfer Time (Ground)

36. The time required to transfer image files from the CRU to the GIU was evaluated following each flight. The time required to transfer 1,000 images from each of three NTTC cameras to the GIU was 4 min 48 sec. If 16 NTTC cameras are considered, the transfer time would be 25 min 36 sec. The ground image transfer time for NTTC images is sufficiently short to allow for multiple flights per day by shortening the time required to deliver the store separation images to the engineer for analysis. If the transfer rate is not increased, the transfer time of LTTC image files (four times larger than the NTTC image files) will be too long for quick turnaround of ASVS images

for analysis. It is anticipated the ground image transfer time associated with the MSC will decrease allowing for quick turnaround of LTTC images for analysis.

Aircraft Store Release Pulse For Camera Trigger

37. The use of the aircraft store release pulse to trigger the ASVS cameras was evaluated as a primary means of initiating an ASVS CAPTURE event to ease pilot workload during a high activity period. During weapon release, the pilot is required to conduct multiple tasks, one of which is flying the test point, often to close tolerances, and one of which is turning the film cameras ON to record the images and then OFF at the completion of the event. In all cases, when selected, the store release pulse accurately activated the ASVS cameras to start recording. The use of the aircraft store release pulse to trigger the ASVS cameras will ensure the cameras are turned ON/OFF at the appropriate time.

LESSONS LEARNED

38. The digital format, smaller file size, and higher contrast of the NTTC images will allow for a quicker turnaround of 6-DOF solutions to the engineer.

39. The aircrew interface to the ASVS will allow real-time Mission changes (image exposure) to increase image quality.

40. The DTS NTTC image quality was sufficient for the near real-time analysis of a store separation event and will allow for multiple releases per flight in a buildup test program.

41. The DTS NTTC image exposure information was sufficient for the determination of optimal image exposure and will allow for improved data quality due to the improved image quality.

42. The use of the aircraft store release pulse to trigger the ASVS cameras will ensure the cameras are turned ON/OFF at the appropriate time.

43. The ease with which the display of digital images could be controlled will facilitate the analysis of ASVS store separation images.

CONCLUSIONS

44. When properly exposed, the ASVS digital images provide sufficient resolution to make qualitative and quantitative analysis consistent with film.

45. When properly exposed, the ASVS system shows excellent potential to improve the efficiency of the aircraft/store certification process.

BIOGRAPHY

Mr. Rob Crandall is an aircraft/weapon compatibility flight test engineer with the Test & Evaluation Engineering Department of the U.S. Naval Air Systems Command at the Naval Air Warfare Center Aircraft Division, Patuxent River, MD. He has been conducting aircraft/stores compatibility testing for the last 9 years on rotary and fixed wing aircraft. Mr. Crandall graduated from San Diego State University in 1983 with a Bachelor of Science in Mechanical Engineering and a Bachelor of Art in Mathematics. Mr. Crandall has been a member of the SFTE since September 1999.